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Yagi et al.

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(54) **METHOD FOR MOUNTING SEMICONDUCTOR ELEMENT TO CIRCUIT BOARD**

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PCT Pub. Date: **Apr. 15, 1999**

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(51) **Int. Cl.**^{7} **H05K 3/34**

(52) **U.S. Cl.** **29/840**; 29/832; 29/841; 29/843; 29/855; 156/285

(58) **Field of Search** 29/832, 840, 841, 29/843, 855, 890; 156/285; 228/1.1, 110.1; 264/230

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(57) **ABSTRACT**

The present invention provides a method for mounting a semiconductor element to a circuit board and a semiconductor device whereby connection reliability and connection strength in bonding of the semiconductor element and circuit board are enhanced and a connection resistance value is stabilized low. An insulating adhesive is applied to an opposite face of a circuit board. The circuit board is then connected with a semiconductor element by a conductive adhesive and the insulating adhesive which are interposed between an electrode on the circuit board and the projecting electrode and set in the same process. The circuit board and semiconductor element are connected by the insulating adhesive in addition to the conductive adhesive, so that connection reliability and connection strength are high and a connection resistance value is stabilized low.

6 Claims, 15 Drawing Sheets

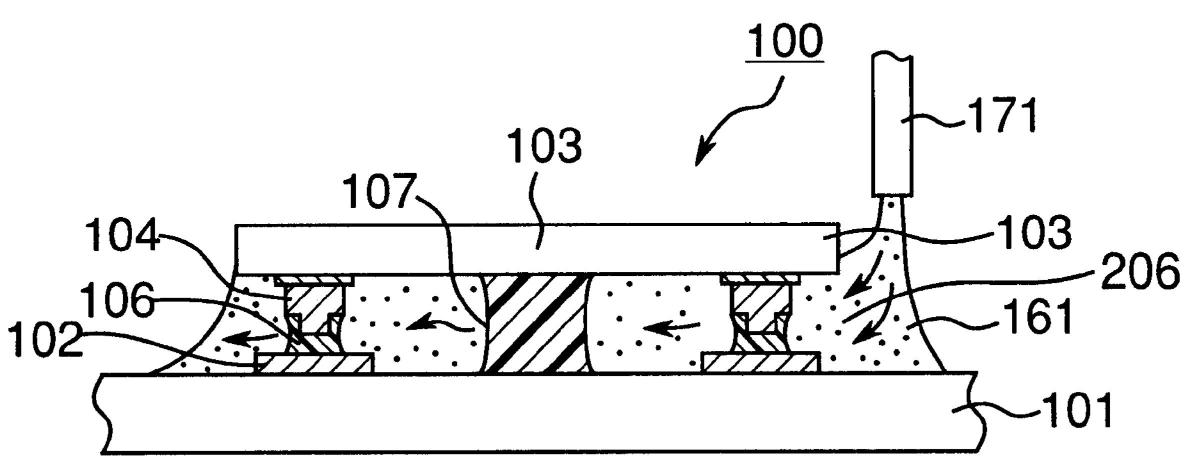

Fig.1

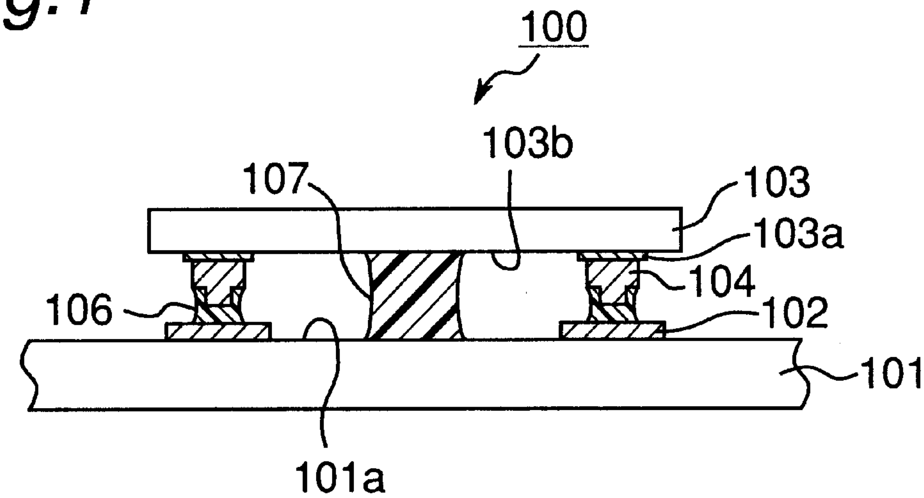

Fig.2

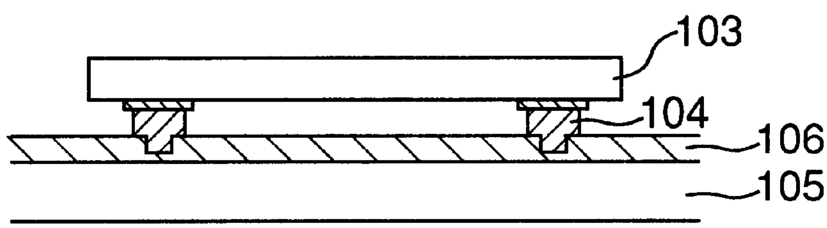

Fig.3

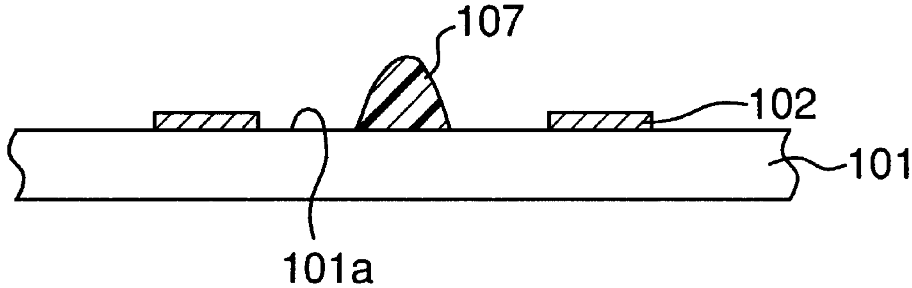

Fig.4

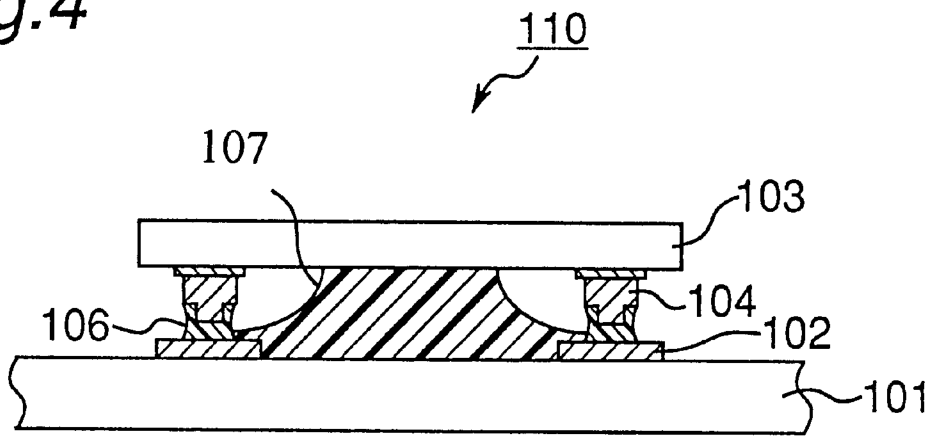

Fig.5

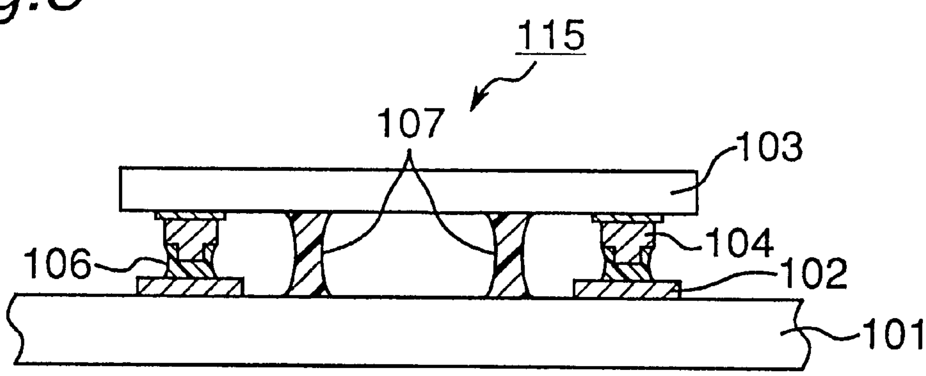

Fig.6

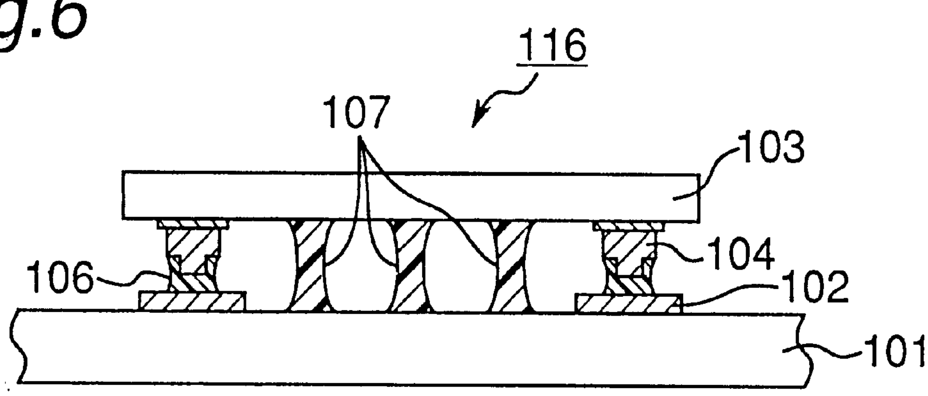

Fig.7

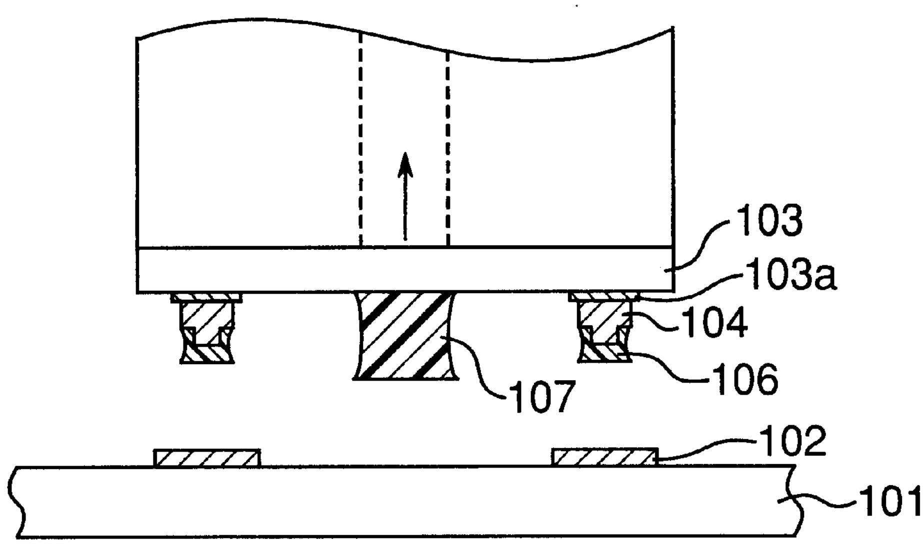

Fig.8

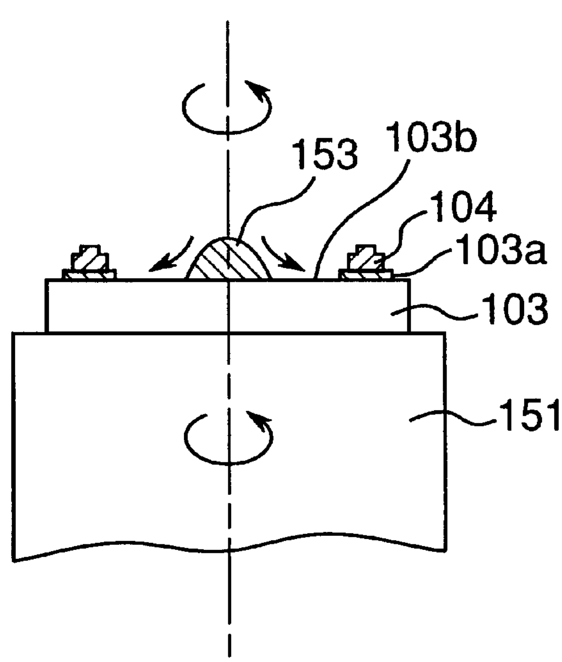

Fig.9

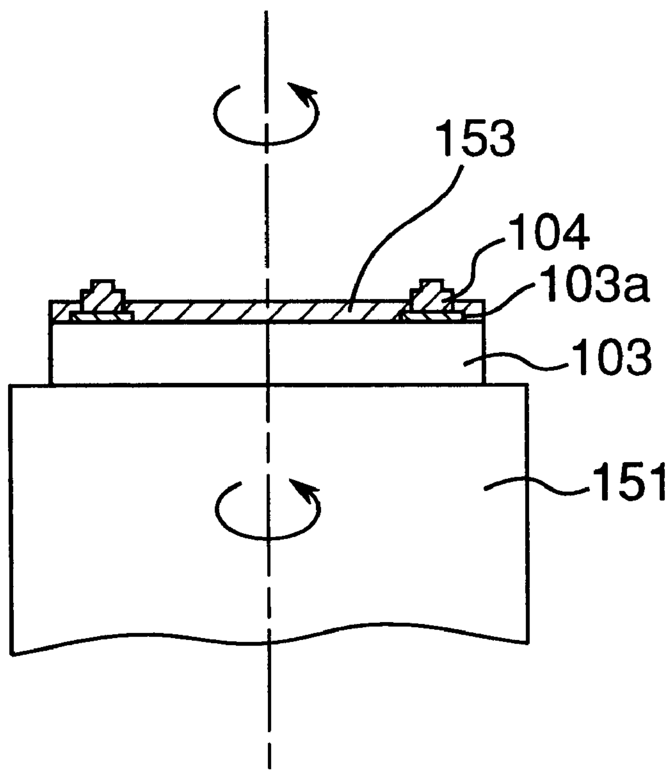

Fig. 10

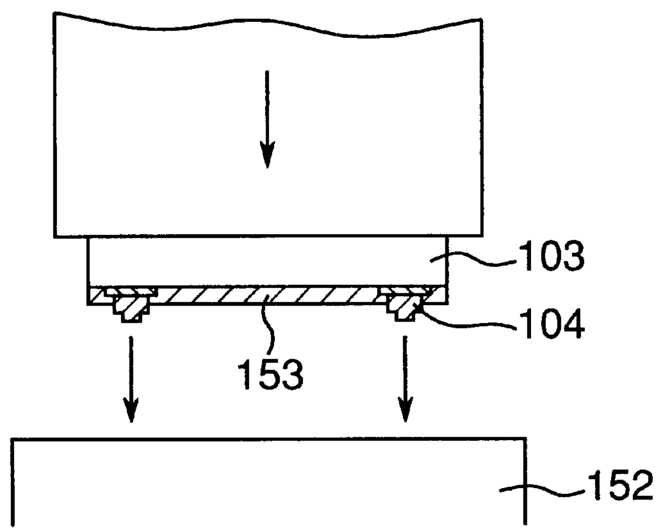

Fig. 11

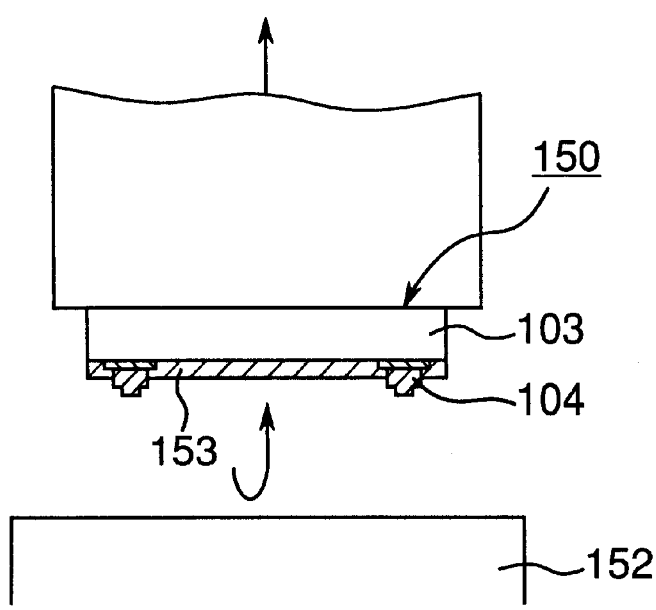

Fig. 12

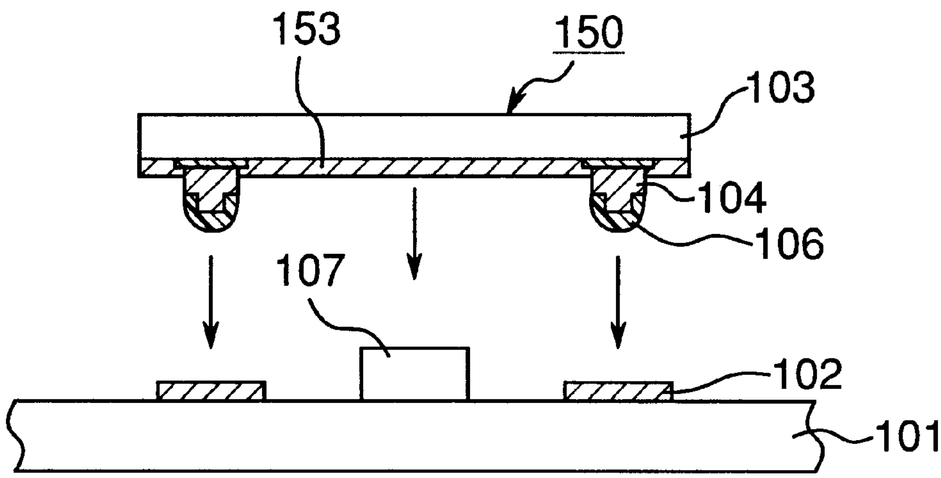
153
150
103
104
106
107
102
101

Fig. 13

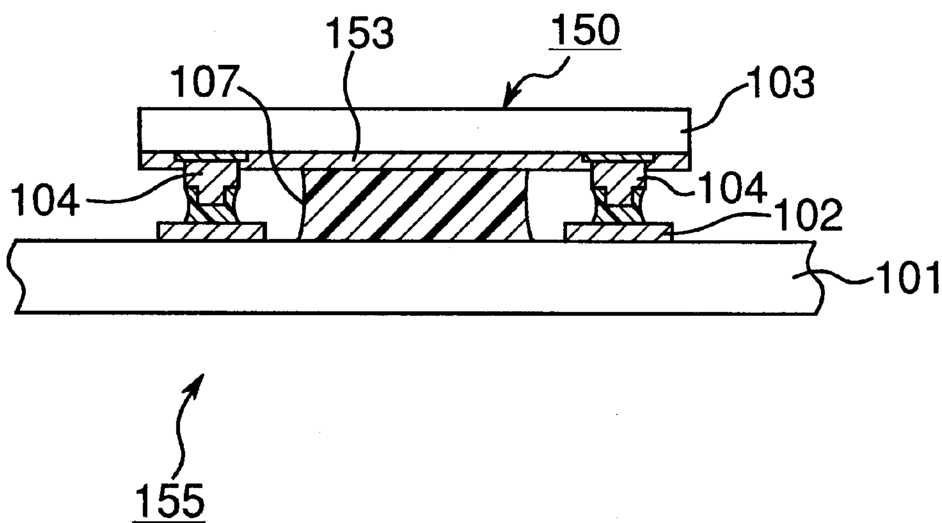
153
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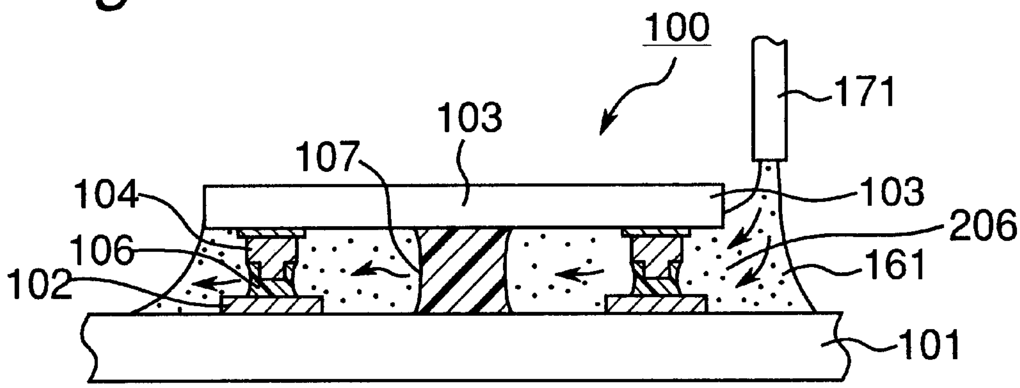
Fig.14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103
107
104
103
206
106
161
102
101

Fig.15

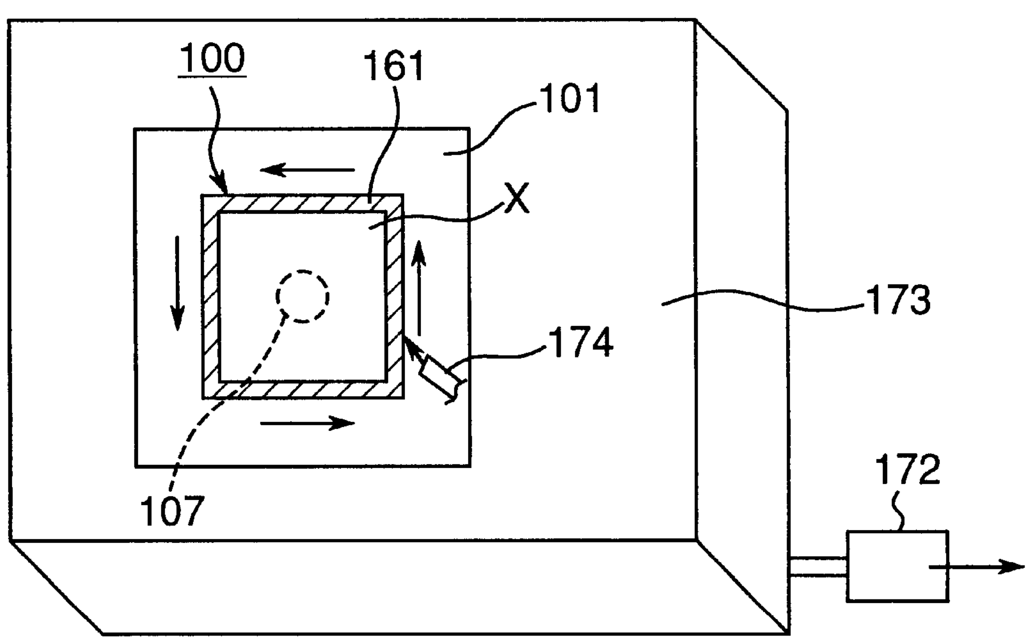

100
161
101
X
173
174
172
107

Fig.16

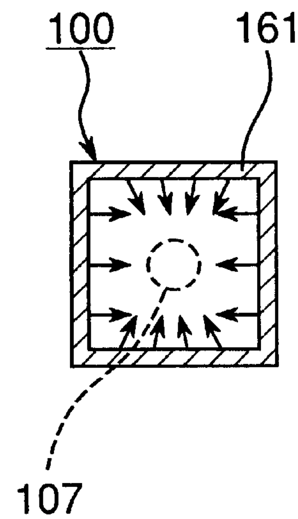


Fig.17

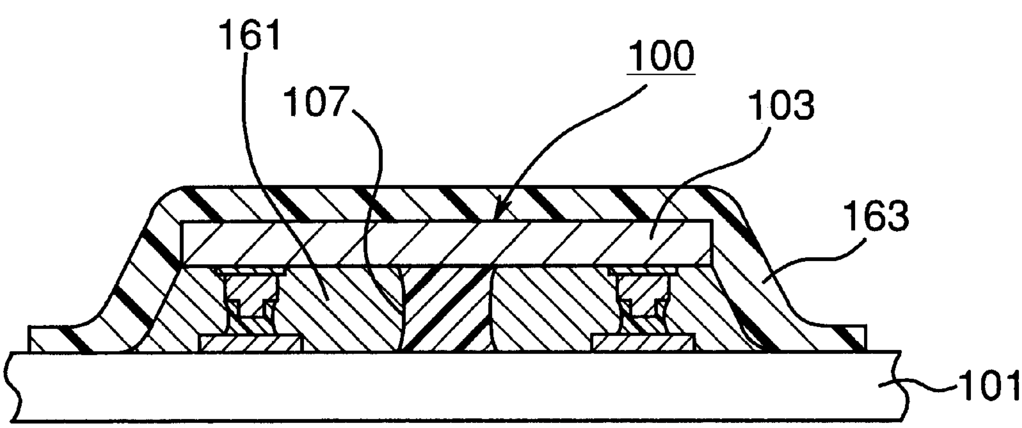


Fig. 18

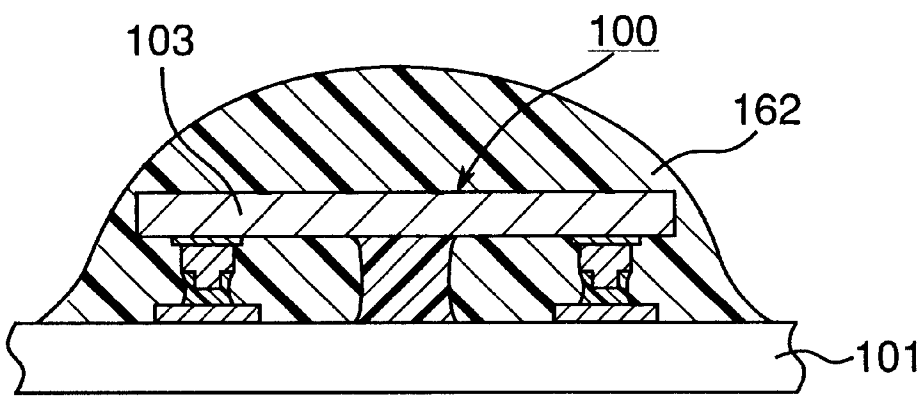


Fig. 19

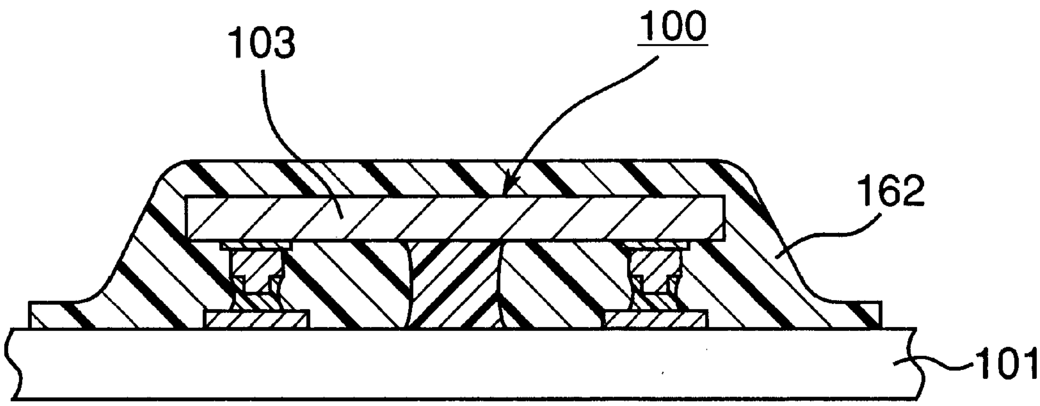


Fig.20

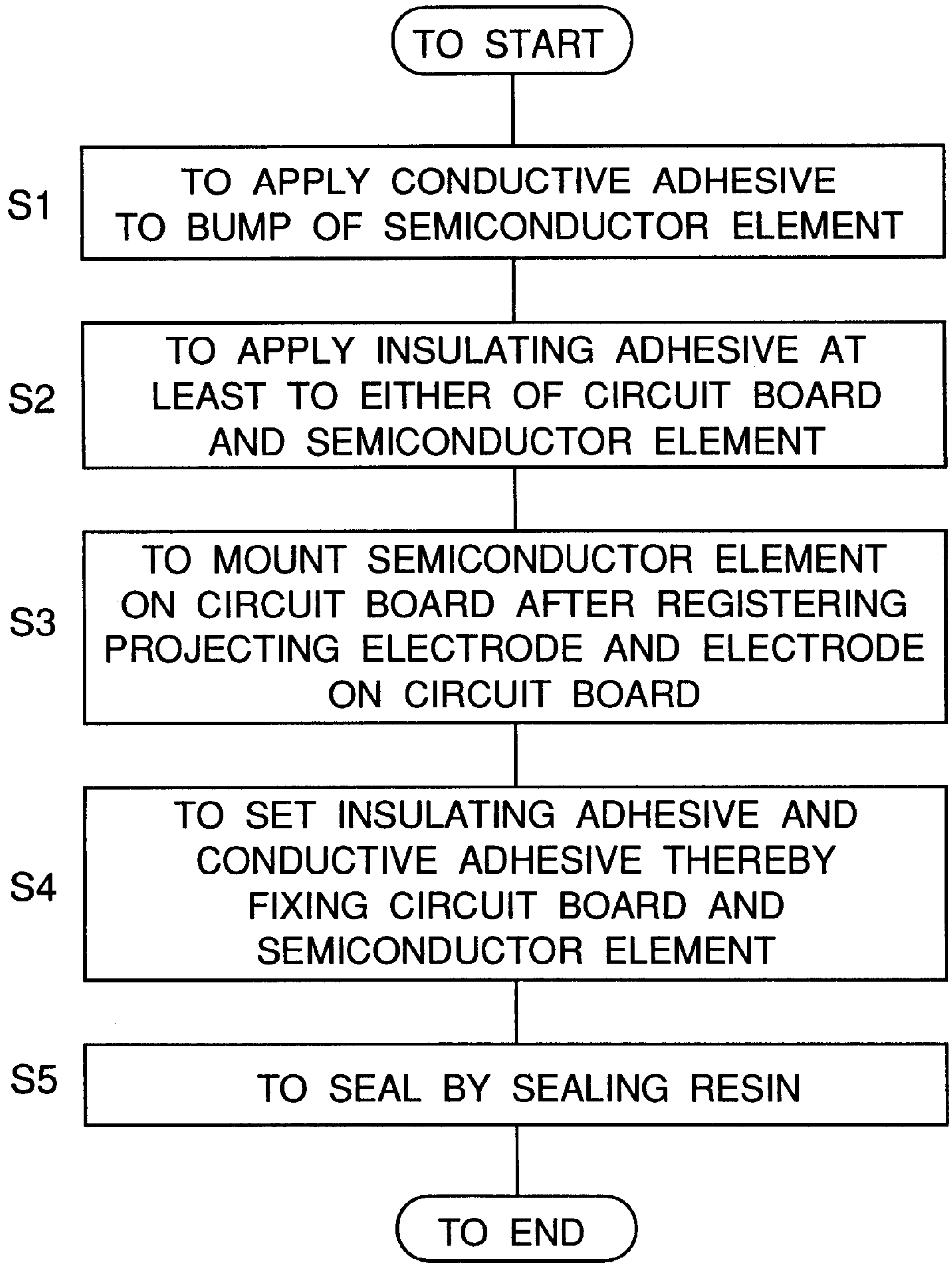

TO START
S1
TO APPLY CONDUCTIVE ADHESIVE TO BUMP OF SEMICONDUCTOR ELEMENT
S2
TO APPLY INSULATING ADHESIVE AT LEAST TO EITHER OF CIRCUIT BOARD AND SEMICONDUCTOR ELEMENT
S3
TO MOUNT SEMICONDUCTOR ELEMENT ON CIRCUIT BOARD AFTER REGISTERING PROJECTING ELECTRODE AND ELECTRODE ON CIRCUIT BOARD
S4
TO SET INSULATING ADHESIVE AND CONDUCTIVE ADHESIVE THEREBY FIXING CIRCUIT BOARD AND SEMICONDUCTOR ELEMENT
S5
TO SEAL BY SEALING RESIN
TO END

Fig.21

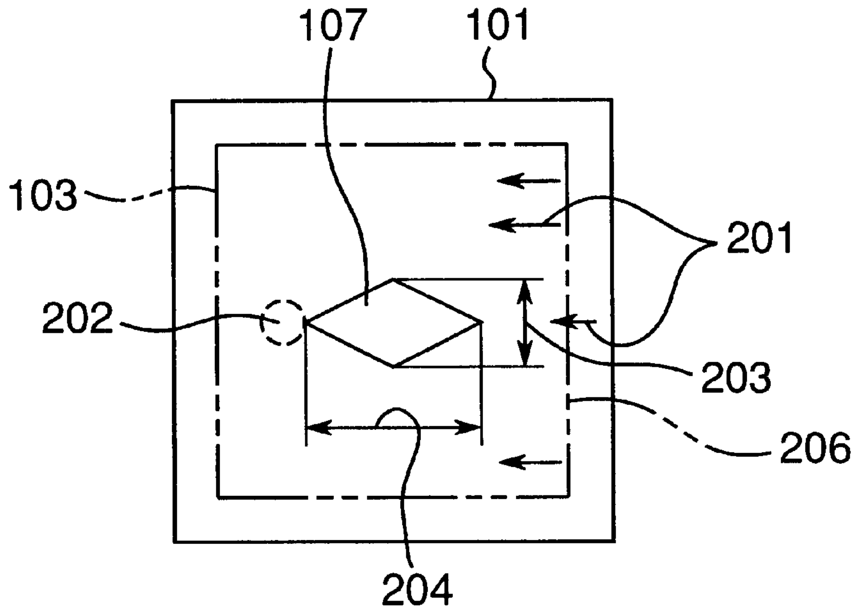


Fig.22

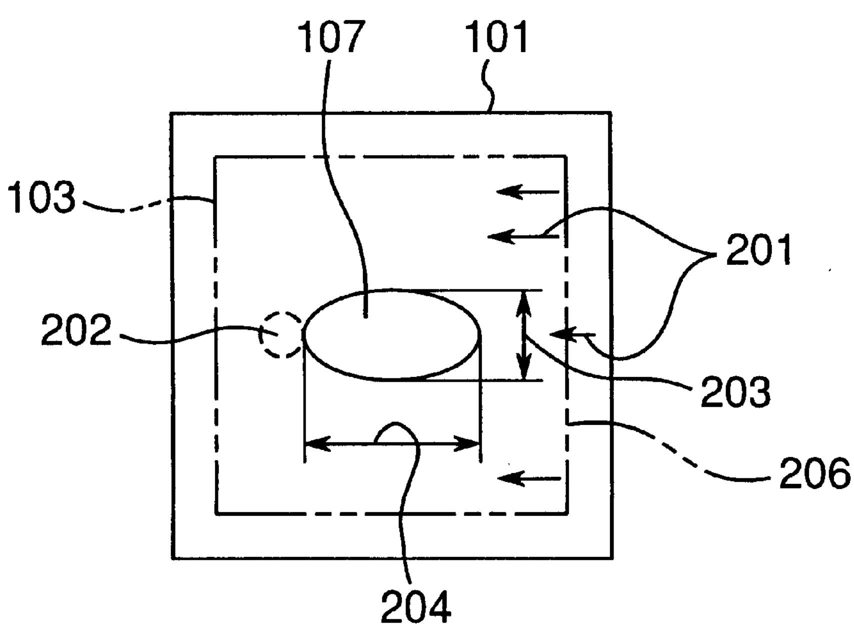
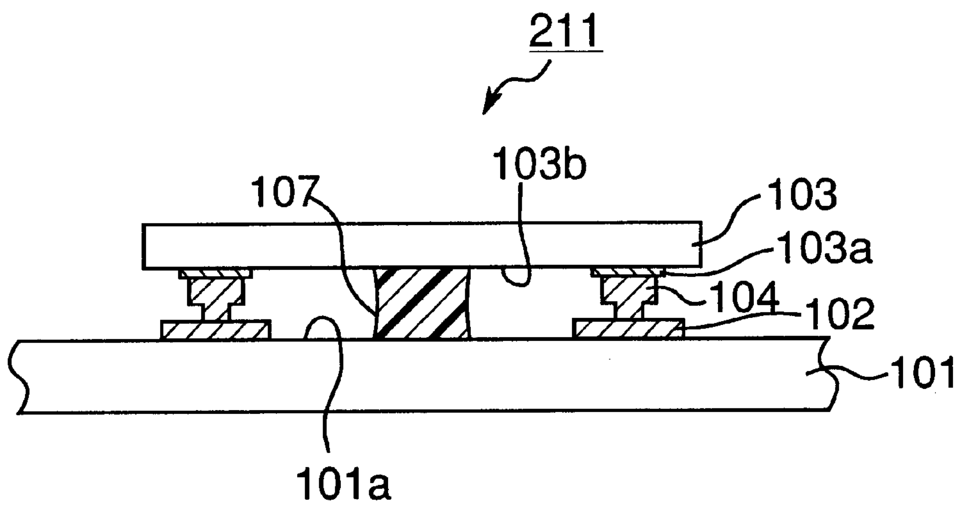


Fig.23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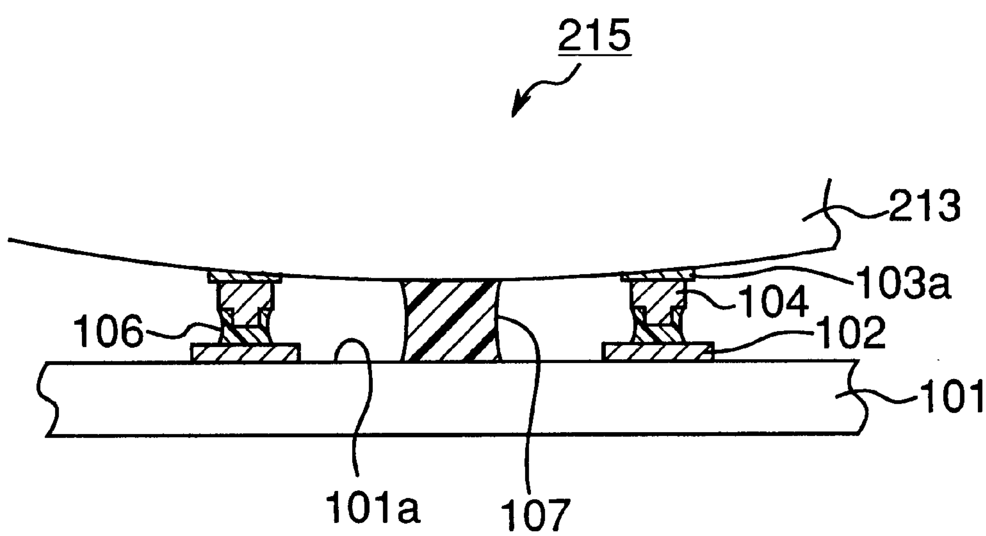
103b
107
103
103a
104
102
101
101a

Fig.24


215
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103a
104
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102
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101a
107

Fig.25 PRIOR ART

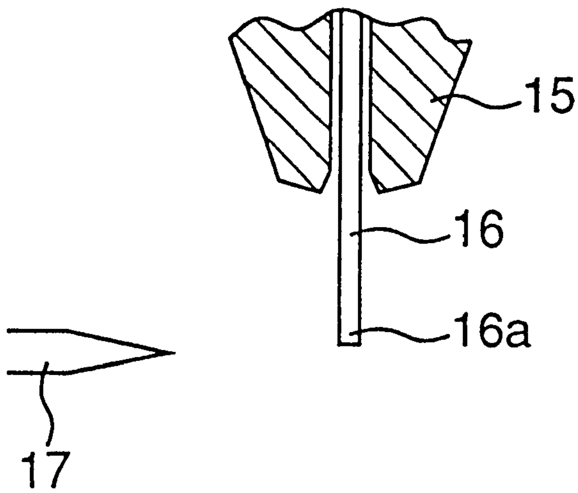


Fig.26 PRIOR ART

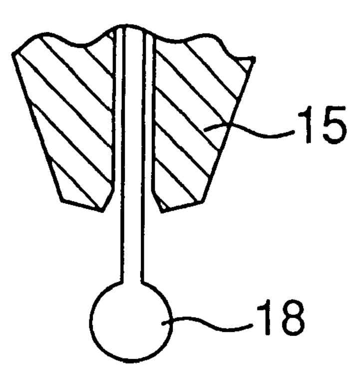


Fig.27 PRIOR ART

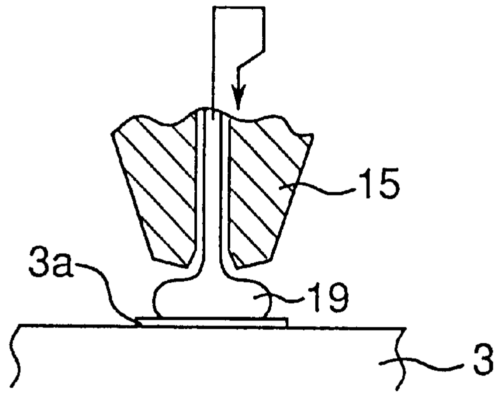


Fig.28 PRIOR ART

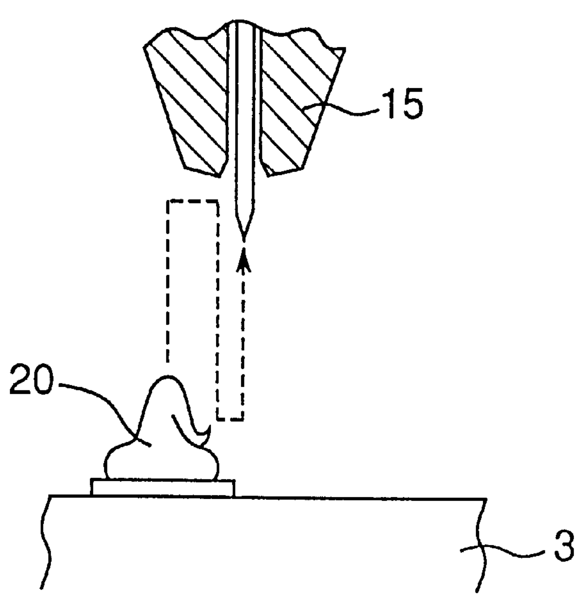


Fig.29 PRIOR ART

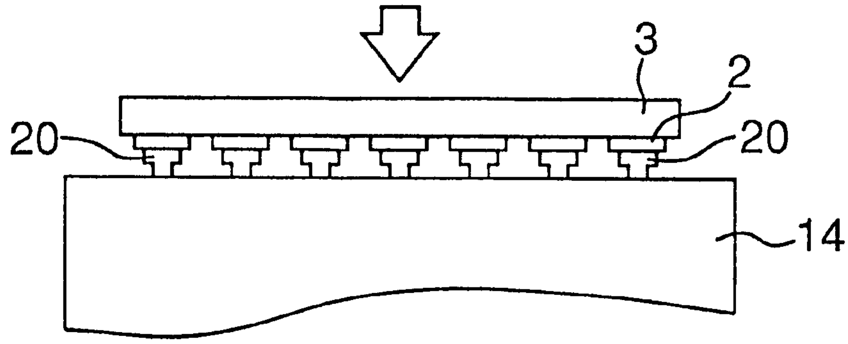


Fig.30 PRIOR ART

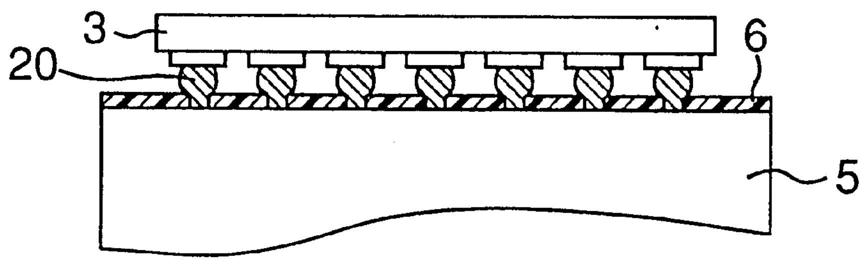
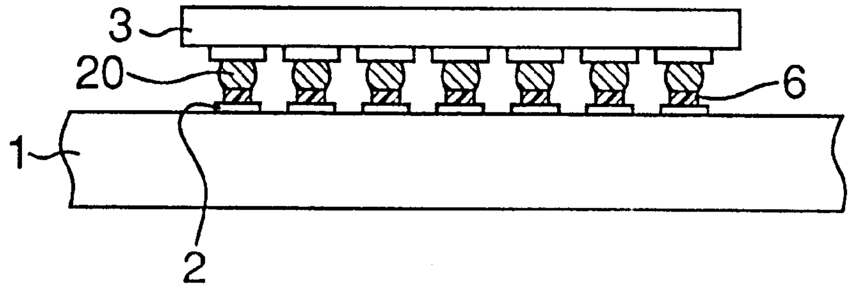


Fig.31 PRIOR ART



METHOD FOR MOUNTING SEMICONDUCTOR ELEMENT TO CIRCUIT BOARD

TECHNICAL FIELD

The present invention relates to a method for mounting a semiconductor element to a circuit board, which is used for electrically connecting projecting electrodes, i.e., bumps on the semiconductor element to electrodes on the circuit board, and a semiconductor device having the semiconductor element mounted on the circuit board according to the method.

BACKGROUND ART

U.S. Pat. No. 4,661,192 discloses in the published specification a method for forming bumps on a semiconductor element by ball bonding and a method for bonding the semiconductor element. The conventional methods will be described.

In FIG. **25**, a high voltage of several thousand volts is impressed from a discharge electrode (torch) **17** to a leading end **16***a* of an Au wire **16** extending from a leading end of a capillary **15**. While a discharge current flows between the torch **17** and the leading end **16***a* of the wire, the wire **16** is heated to a high temperature from the leading end **16***a* and then melted, resulting in a gold ball **18** as shown in FIG. **26**. The ball **18** is fixed onto an electrode **3***a* of a semiconductor element **3** by the capillary **15**, thereby forming a bump bottom part **19** as in FIG. **27**. Thereafter, the capillary **15** is pulled upward as in FIG. **28**. The capillary **15** is looped above the bump bottom part **19**, so that the wire **16** is tightly adhered to the bump bottom part **19**, and then the wire is cut. A bump **20** is formed in this manner.

A semiconductor element **3** having the bumps **20** formed as above is pressed against a stage **14** having a flat face as shown in FIG. **29**. As a result thereof, leading end parts of the bumps **20** are flattened. Then, as indicated in FIG. **30**, the semiconductor element **3** with the flattened bumps **20** is brought into contact with a conductive adhesive **6** applied on a stage **5** to transfer the conductive adhesive **6** to the flattened bumps **20**. In FIG. **31**, the semiconductor element **3** having the bumps **20** with the conductive adhesive **6** transferred thereon is registered with electrodes **2** on a circuit board **1** and then fixed thereto, whereby the semiconductor element is electrically connected to the circuit board **1**.

As described hereinabove, conventionally, the semiconductor element **3** and circuit board **1** are bonded only by the conductive adhesive **6** transferred to the bumps **20** of the semiconductor element **3**. As such, the bonding between the semiconductor element **3** and circuit board **1** has merely a bonding strength of an area at the leading ends of the bumps **20** of the semiconductor element **3**, and the conductive adhesive **6** exerts a strength as low as 1–2.0 g at every bonded part because only a small amount of the conductive adhesive **6** is used so as to lower a volume resistivity. Such inconveniences are realized when the bonded part cracks because of a warp of the circuit board **1** or a stress when the conductive adhesive **6** is set, a connection resistance value is increased, and a disconnection at the bonded part arises.

SUMMARY OF THE INVENTION

An object of the present invention is therefore to provide a method for mounting a semiconductor element to a circuit board whereby connection reliability and connection strength are enhanced in bonding between the semiconductor element and circuit board, and a connection resistance value is stabilized to be low. Another object is to provide a semiconductor device having a semiconductor element mounted to a circuit board by the method.

In order to accomplish the above-described objects, according to a first aspect of the present invention, a method is provided for mounting a semiconductor element to a circuit board. The method comprises:

- disposing an insulating adhesive having a property of shrinking upon being set, at least at either of opposite faces confronting each other of the circuit board and the semiconductor element;
- registering the circuit board and the semiconductor element so that an electrode on the circuit board corresponds to a projecting electrode on the semiconductor element;
- coupling the opposite faces of the circuit board and semiconductor element by the insulating adhesive; and
- setting the insulating adhesive, so that the electrode on the circuit board and the projecting electrode on the semiconductor element are electrically connected through the shrinkage of the insulating adhesive such that the semiconductor element and circuit board are fixed in a coupled state.

A semiconductor device according to a second aspect of the present invention has a semiconductor element mounted to a circuit board according to the above mount method of the first aspect.

According to the mount method for a semiconductor element to a circuit board of the first aspect and the semiconductor device of the second aspect, the semiconductor element and circuit board are connected with the use of the insulating adhesive, and therefore connected rigidly in comparison with the conventional art whereby the connection is achieved only by the projecting electrodes of the semiconductor element and the electrodes of the circuit board. Therefore, a connection resistance value at a projecting electrode of the semiconductor element and a corresponding electrode of the circuit board is reduced and less varied, and at the same time, connection strength is high, thereby realizing highly reliable bonding.

BRIEF DESCRIPTION OF DRAWINGS

These and other aspects and features oft he present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings in which:

FIG. **1** is a sectional view showing the structure of a semiconductor device in an embodiment of the present invention;

FIG. **2** is a diagram of one step of a manufacture process of the semiconductor device of FIG. **1**, particularly in a state where a conductive adhesive is transferred to projecting electrodes of a semiconductor element;

FIG. **3** is a diagram of one step of the manufacture process of the semiconductor device of FIG. **1**, particularly in a state where an insulating adhesive is transferred onto a circuit board;

FIG. **4** is a sectional view of a modified example of the semiconductor device of FIG. **1**;

FIG. **5** is a sectional view of a further modified example of the semiconductor device of FIG. **1**;

FIG. **6** is a sectional view of a yet another modified example of the semiconductor device of FIG. **1**;

FIG. **7** is a diagram of a state where a part of the semiconductor element is removed in the semiconductor device of FIG. **1**;

FIG. **8** is a diagram of one step of the manufacture process in a modified example of the semiconductor device of FIG. **1**;

FIG. **9** is a diagram of one step of the manufacture process of the modified example of the semiconductor device of FIG. **1**, specifically, a succeeding step to FIG. **8**;

FIG. **10** is a diagram of one step of the manufacture process of the modified example of the semiconductor device of FIG. **1**, specifically, a succeeding step to FIG. **9**;

FIG. **11** is a diagram of one step of the manufacture process of the modified example of the semiconductor device of FIG. **1**, specifically, a succeeding step to FIG. **10**;

FIG. **12** is a diagram of one step of the manufacture process of the modified example of the semiconductor device of FIG. **1**, specifically, a succeeding step to FIG. **11**;

FIG. **13** is a sectional view of a modified example of the semiconductor device of FIG. **1**;

FIG. **14** is a diagram of a state where a sealing resin is injected into the semiconductor device of FIG. **1**;

FIG. **15** is a diagram showing the constitution of an apparatus for injecting the sealing resin into the semiconductor device of FIG. **1**;

FIG. **16** is a diagram of a state where the sealing resin is being injected into the semiconductor device of FIG. **1**;

FIG. **17** is a sectional view of the semiconductor device of FIG. **1** with the sealing resin injected while coated with a heat-radiating resin;

FIG. **18** is a sectional view of the semiconductor device of FIG. **1** in a state where a second sealing resin is applied thereto;

FIG. **19** is a sectional view of the semiconductor device of FIG. **1** in a state where the second sealing resin is applied thereto;

FIG. **20** is a flow chart of an operation of a method for mounting a semiconductor element to a circuit board according to an embodiment of the present invention;

FIG. **21** is a plan view of an arrangement of a rectangular insulating adhesive when the sealing resin is injected into the semiconductor device of FIG. **1** in one direction;

FIG. **22** is a plan view of an arrangement of an elliptical insulating adhesive when the sealing resin is injected into the semiconductor device of FIG. **1** in one direction;

FIG. **23** is a sectional view of the semiconductor device of an embodiment in another structure without using a conductive adhesive;

FIG. **24** is a sectional view of the semiconductor device of an embodiment in a different structure using a spherical semiconductor element;

FIG. **25** is a diagram of one step of a process for forming a projecting electrode on an electrode of a semiconductor element, specifically indicating a leading end part of a capillary;

FIG. **26** is a diagram of one step of the process for forming the projecting electrode on the electrode of the semiconductor element, specifically showing a state with a ball formed at the leading end of the capillary;

FIG. **27** is a diagram of one step of the process for forming the projecting electrode on the electrode of the semiconductor element, specifically showing a state with the ball of FIG. **26** pressed to the electrode on the semiconductor element;

FIG. **28** is a diagram of one step of the process for forming the projecting electrode on the electrode of the semiconductor element, specifically showing a state with the projecting electrode formed on the electrode on the semiconductor element;

FIG. **29** is a diagram of one step of the process for forming the projecting electrode on the electrode of the semiconductor element, specifically showing a state where projecting electrodes are made uniform in height;

FIG. **30** is a diagram of one step of the process for forming the projecting electrode on the electrode of the semiconductor element, specifically showing a state where a conductive adhesive is transferred to the projecting electrodes;

FIG. **31** is a diagram of a conventional semiconductor device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A method for mounting a semiconductor element to a circuit board according to a preferred embodiment of the present invention, and a semiconductor device having a semiconductor element mounted to a circuit board by the method will be described with reference to the drawings throughout which like parts are designated by like reference numerals.

FIG. **1** shows a semiconductor device **100** in which a semiconductor element **103** is mounted to a circuit board **101** according to a mount method in the preferred embodiment. The mount method for obtaining the semiconductor device **100** will be discussed hereinbelow.

Similar to the conventional semiconductor element described with reference to FIGS. **25–29**, a projecting electrode **104** as a bump is formed on an electrode **103***a* of the semiconductor element **103**. The projecting electrodes **104** are pressed to a flat face of a stage, so that leading end parts of the projecting electrodes are flattened and at the same time, made uniform in height from a surface of the semiconductor element **103**. The projecting electrodes **104** are preferably formed of Au, Ni, Al, Cu or solder by plating or conventional ball bonding with the use of a wire described earlier. The formation method is not limited to the above.

As indicated in FIG. **2** and a step S1 in FIG. **20**, each leading end part of the projecting electrodes **104** of the semiconductor element **103** is brought into contact with a conductive adhesive **106** applied on the flat face of the stage, whereby the conductive adhesive **106** is transferred to the leading end parts. The conductive adhesive **106** is any kind of filler having conductive properties, e.g., silver, gold or the like and not limited in material.

On the other hand, as shown in FIG. **3** and a step S2 in FIG. **20**, in forming the semiconductor device **100** according to the present embodiment, a thermosetting insulating adhesive **107** is applied on an opposite face **101***a* confronting the semiconductor element **103** at a position not in touch with electrodes **102** which are to be connected to the projecting electrodes **104**. Concretely, the insulating adhesive **107** is anything such as an epoxy-series resin, a silicone-series resin, a polyimide-series resin, etc. so long as it shrinks and sets by heat. As will be described later, the insulating adhesive **107** is heated in a range of 60–200° C., preferably at 120° C. in the case of the epoxy-series resin for 15 minutes to 2 hours, preferably for one hour so as to set and shrink in the same process that the conductive adhesive **106** of the projecting electrodes **104** is set. Moreover, because of the need for the insulating adhesive **107** on the circuit board **101** to adhere to an opposite face **103***b* of the semiconductor element **103** to thereby couple the opposite faces **101***a* and **103***b* when the semiconductor element **103** is arranged on the circuit board **101**, the insulating adhesive **107** should be formed like a projection on the circuit board **101** as illustrated in FIG. **3** if the insulating adhesive **107** is in liquid state. For this reason, the insulating adhesive **107** has, when it is in liquid state, a viscosity of 4–300 Pas, preferably 30 Pas.

In the description of the embodiment, the semiconductor element **103** to which the insulating adhesive **107** is applied or adhered is exemplified in the form of one chip, but not restricted to this form and may be a wafer before cut to one chip.

An example of physical properties of the insulating adhesive **107** formed of epoxy-series resin is indicated hereinbelow. The insulating adhesive **107** is set by heating at 120° C. for 30 minutes. A thermal expansion coefficient is $29\times10^{-6}/°$ C., a Young's modulus is 10.5 GPa, a glass transition point is 113° C., a bonding strength is 88.26 N and a setting stress is 882.6×10^{6} Pa.

The setting stress applied to the semiconductor element **103** when the insulating adhesive **107** is set and shrunken has the risk of causing damage to the semiconductor element **103**. While the setting stress changes in accordance with a thickness and a size of the semiconductor element **103**, a material and a breadth of a wiring, and a thickness, a size and a material of the circuit board **101**, when the semiconductor element is silicon and is 0.4 mm thick and 10 mm square, and the circuit board is formed of 0.8 mm thick glass epoxy resin, the setting stress within 392.3×10^{6}–1176.8×10^{6} Pa never damages the semiconductor element. In other words, if the insulating adhesive **107** used applies the setting stress as above to the semiconductor element **103** and circuit board **101** when set and shrunken, the damage to the semiconductor element **103** and circuit board **101** can be avoided.

In step S**3** of FIG. **20**, the projecting electrodes **104** of the semiconductor element **103** are registered on the electrodes **102** of the circuit board **101** and subsequently bonded to the electrodes **102** on the circuit board **101** by the conductive adhesive **106**. As a result of the registering, the interposed insulating adhesive **107** couples the opposite face **101***a* of the circuit board **101** to the opposite face **103***b* of the semiconductor element **103** between the semiconductor element **103** and circuit board **101**.

Then in step S**4** of FIG. **20**, the semiconductor element **103** and circuit board **101**, i.e., the conductive adhesive **106** and insulating adhesive **107** are set in the same process by a cure oven heating and setting the insulating adhesive **107** and conductive adhesive **106**, or by a heating tool with a heater heating at least one of the semiconductor element **103** and circuit board **101**. As a result, the semiconductor device **100** shown in FIG. **1** is obtained. At this time, the circuit board **101** and semiconductor element **103** are not temporarily fixed, but permanently set by the setting of the conductive adhesive **106** and insulating adhesive **107**.

A heating temperature in the cure oven is 120±10° C. in the embodiment in the case of the epoxy-series resin adhesive. The conductive adhesive **106** and insulating adhesive **107** are set under the same conditions.

In the step S**4**, the insulating adhesive **107** is adapted to be set and shrunken earlier than the conductive adhesive **106**. The reason for adapting such timing is that if the conductive adhesive **106** were set earlier in a state without the projecting electrodes **104** and the electrodes **102** on the circuit board **101** bonded, the defective bonded state cannot be repaired after the setting and shrinking of the insulating adhesive **107**. The setting is executed with a timing, for instance, that the insulating adhesive **107** is set and shrunken in 25 minutes and the conductive adhesive **106** is set in 40 minutes at a setting temperature of 100° C., the insulating adhesive **107** is set and shrunken in 20 minutes and the conductive adhesive **106** is set in 35 minutes at a setting temperature of 120° C., or the insulating adhesive **107** is set and shrunken in 10 minutes and the conductive adhesive **106** is set in 20 minutes at a setting temperature of 150° C.

In order to set and shrink the insulating adhesive **107** earlier than the conductive adhesive **106** with the above-described timing, and also to surely bond the projecting electrodes **104** to the electrodes **102** on the circuit board **101** by the insulating adhesive **107** that has set and shrunk earlier without causing damage, e.g., cracks or the like to the semiconductor element **103**, the insulating adhesive **107** that has the above-described physical properties is employed. Moreover, in order to secure a timing shift of the setting, the insulating adhesive **107** is adapted to have a gelling time and a setting time which are earlier than those of the conductive adhesive **106**. Further, the insulating adhesive **107** is adapted to be set at a lower temperature so as not to damage the semiconductor element **103** by the setting and shrinking thereof. A difference of the gelling time and the setting time between the insulating adhesive **107** and conductive adhesive **106** is due to a difference of components. That is, the insulating adhesive **107** is set as an adhesive component contained in the insulating adhesive **107** is set, while, the conductive adhesive **106** is dried and solidified when a solvent component such as BCA (butyl Carbitol acetate) contained in the conductive adhesive **106** evaporates. The presence/absence of the solvent component is one reason for the difference of the gelling time and setting time.

The setting stress applied to the semiconductor element **103** and circuit board **101**, i.e., internal stress changes corresponding to a setting temperature, for example, 490.3×10^{6} Pa at 100° C. for 30 minutes, 882.6×10^{6} Pa at 120° C. for 30 minutes and 1520.OX 10^{6} Pa at 150° C. for 15 minutes. Therefore, not only the timing shift of the setting is required, but the setting stress should be 392.3×10^{6}–1176.8×10^{6} Pa as mentioned earlier.

Since the semiconductor element **103** and circuit board **101** are connected by the insulating adhesive **107** as well as by the conductive adhesive **106**, connection strength between the circuit board **101** and semiconductor element **103** is increased due to the setting and shrinking of the insulating adhesive **107** as compared with the conventional art in spite of the stress impressed to the connected part between the projecting electrodes **104** and electrodes **102** of the circuit board **101** due to a difference of thermal expansion coefficients of the circuit board **101** and semiconductor element **103**, and a warp of the circuit board **101**. Accordingly, a connection resistance between the projecting electrodes **104** and electrodes **102** of the circuit board **101** is decreased and less varied, and at the same time, the semiconductor element **103** and circuit board **101** are bonded stably and highly reliably with a large connection strength.

Although the insulating adhesive **107** is applied onto the circuit board **101** in order to simplify the manufacture process in the foregoing description, the insulating adhesive **107** may be applied to the opposite face **103***b* of the semiconductor element **103**, or both opposite faces **101***a* and **103***b* of the circuit board **101** and semiconductor element **103**.

In addition, although the insulating adhesive **107** is applied only at one point between the semiconductor element **103** and circuit board **101** as indicated in FIG. **1**, the present invention is not limited to this and the insulating adhesive **107** can be applied at a plurality of points as in semiconductor devices **115**, **116** shown in FIGS. **5**, **6** in accordance with an increase of an area of the semiconductor element **103**. When the insulating adhesive **107** is applied at two or more points, the amount of the insulating adhesive **107** applied once is reduced, so that variations in the application amount is decreased, thereby enabling a constant amount of the insulating adhesive **107** to be applied. The insulating adhesive **107** is prevented from spreading to the electrodes **102** of the circuit board **101** when the semiconductor element **103** is mounted on the circuit board **101**.

When the semiconductor element **103** and circuitboard **101** are connected with each other as in FIGS. **1**, **5** and **6**, if the insulating adhesive **107** is disposed so as not to adhere any of the electrodes **103***a* of the semiconductor element **103** and electrodes **102** of the circuit board **101**, the following effects are realized. In the event the semiconductor element **103** is detected to be defective after being mounted to the circuit board, the insulating adhesive **107** of epoxy-series resin not adhering to at least one of the electrodes **102** on the circuit board **101** can be softened by heating the defective semiconductor element to about 200–230° C., which is a temperature not lower than the glass transition point of the insulating adhesive, to be reduced in bond strength. The insulating adhesive **107** can hence be separated from the circuit board **101**, and the semiconductor element **103** can be removed in about 15 seconds from the circuit board **101**. Thus, the circuit board **101** can be used again, to which a good semiconductor element **103** can be mounted.

Although the aforementioned effect is lost, the insulating adhesive **107** may be disposed to adhere to the electrode **102** of the circuit board **101** as in a semiconductor device **110** of FIG. **4**, or adhere to both the electrode **103** a of the semiconductor element **103** and the electrode **102** of the circuit board **101**.

The insulating adhesive **107** in the foregoing description is in liquid state. However, the insulating adhesive may be molded into a pellet or be a film, whereby the amount of the insulating adhesive **107** supplied varies less. The insulating adhesive **107** of a constant amount can be supplied.

At this time, the insulating adhesive **107** shaped as a pellet or film is preferably rectangular or elliptical in a plane and has a length-to-breadth ratio of not smaller than 1. As will be described later, a first sealing resin **161** is injected into a gap between the semiconductor element **103** and circuit board **101** as shown in FIG. **14** after the semiconductor element **103** and circuit board **101** are fixed by the insulating adhesive **107**. When the first sealing resin **161** is injected into the gap from a side end face and a neighboring part **206** of the semiconductor element **103** in one direction as represented by arrows **201** in FIGS. **21** and **22**, air bubbles are formed at a rear end part **202** of the insulating adhesive **107** in the injection direction of the arrow **201**, resulting in the formation of a void part. For eliminating the air bubbles, therefore, the insulating adhesive **107** is arranged to be streamlined in the injection direction, and further the insulating adhesive **107** is arranged in plane so that a ratio of a lateral size **204** thereof in the injection direction of the arrow **201** to a longitudinal size **203** thereof in a direction orthogonal to the injection direction is not smaller than 1.

The above condition of the length-and-breadth ratio of not smaller than 1 can be applied also to a planar shape of the applied insulating adhesive **107** when the insulating adhesive **107** is in liquid state. Since it is necessary for the pellet or film-shaped insulating adhesive **107** on the circuit board **101** to touch the opposite face **103***b* of the semiconductor element **103** when the semiconductor element **103** is mounted on the circuit board **101**, a height of the pellet or film-shaped insulating adhesive **107** from the opposite face **101***a* of the circuit board **101** is such that allows this touching. For example, the pellet or film in a plane is smaller than a distance between the electrodes **103***a* of the semiconductor element **103** shown in FIG. **1** and has a height slightly greater than a distance between the semiconductor element **103** and circuit board **101**, i.e., 20–200 μm.

In the case where the pellet or film-shaped insulating adhesive **107** is employed, the following effects are realized. As described earlier, when the insulating adhesive **107** in a liquid state is used, an application operation for the insulating adhesive **107** and a mount operation for the semiconductor element **103** onto the circuit board **101** are carried out separately as in steps S2 and S3 in FIG. **20**. To the contrary, when the pellet or film-shaped insulating adhesive **107** is used, since the adhesive is solid, the pellet or film-shaped insulating adhesive **107** can be disposed between the circuit board **101** and semiconductor element **103** while the aforementioned mount operation is being performed.

Although the insulating adhesive **107** is directly adhered to the opposite face **103***b* of the semiconductor element **103** in the above description, as will be depicted later, an insulating resin **153** of, e.g., an epoxy-series resin may be formed at the opposite face **103***b* of the semiconductor element **103** beforehand, thereby constituting a semiconductor element **150**, and thereafter the semiconductor element **150** is connected with the circuit board **101** by the insulating adhesive **107**. More specifically, referring to FIG. **8**, after the projecting electrodes **104** are formed on the electrodes **103***a* of the semiconductor element **103**, the semiconductor element **103** is fitted on a rotary table **151**. The insulating resin **153** is applied to a nearly central part on the opposite face **103***b* of the semiconductor element **103**, and the rotary table **151** is rotated in the direction of the arrow. As a result thereof, as in FIG. **9**, the insulating resin **153** is spread by a centrifugal force, so that the opposite face **103***b* of the semiconductor element **103** and the electrodes **103***a* on the periphery of the projecting electrodes **104** are covered with the insulating resin **153**. But leading end parts of the projecting electrodes **104** are exposed from the insulating resin **153**. The insulating resin **153** is then set. After the setting, the leading end parts of the projecting electrodes **104** are pressed against a base material **152** having a flat face, as shown in FIGS. **10** and **11**, thereby making the leading end parts of the projecting electrodes **104** flat and exposed as a bond face. Afterwards, as in FIGS. **12** and **13**, the conductive adhesive **106** is provided at the leading end parts of the projecting electrodes **104** as described earlier, and the insulating adhesive **107** is disposed between the semiconductor element **150** and circuit board **101**, whereby the semiconductor element **150** is connected to the circuit board **101**. The semiconductor device thus manufactured becomes a semiconductor device **155** shown in FIG. **13**.

As described hereinabove, when the insulating resin **153** is formed on the opposite face **103***b* of the semiconductor element **103**, the insulating resin **153** protects the semiconductor element **103** and also the electrodes **103***a* on the periphery of the projecting electrodes **104**, and at the same time, makes the semiconductor element superiorly resistive to moisture after being mounted on the circuit board **101** and prevents the electrodes **103***a* of the semiconductor element **103** from being corroded. According to the semiconductor device **155**, a process of injecting and setting an insulating resin in a gap between the circuit board **101** and semiconductor element **103** is effectively eliminated.

While the insulating resin **153** may not contain a material such as silica or the like controlling the thermal expansion of the insulating resin **153**, if the insulating resin contains this material, it becomes almost equal to the insulating adhesive **107** in terms of components, thereby reducing a stress at an interface between the insulating resin **153** and insulating adhesive **107**.

In each of the above-described semiconductor devices **100**, **110**, **115**, **116**, **155**, the first sealing resin **161** is injected into the gap between the semiconductor element and circuit board, e.g., in a manner as illustrated in FIG. **14** or in step **S5** of FIG. **20**. The injection of the first sealing resin **161** may be omitted in the semiconductor device **155** as discussed above. An injection operation of the first sealing resin **161** will be described now by way of example of the semiconductor device **100**.

As a manner of the injection method, the first sealing resin **161** is injected by a resin injection device **171** from the side end face of the semiconductor device **100** and one of parts in the vicinity of the side end face, as indicated by the reference numeral **206** in FIG. **14**.

Preferably, the interior of a working chamber **173** is reduced in pressure lower than atmospheric pressure by an air discharge device **172** after the semiconductor device **100** is set in the chamber **173**. Under the pressure-reduced state, the first sealing resin **161** is applied onto the circuit board **101** along four sides of the semiconductor device **100** from the side end face and the neighboring part **206** of die semiconductor device **100** via a resin feed device **174** as represented by arrows. After the application is completed, the interior of the chamber **173** is returned to atmospheric pressure. Meanwhile, the gap part between the semiconductor element **103** and circuit board **101** sealed by the first sealing resin **161** applied along the four sides of the semiconductor device **100** is still in a pressure-reduced state. Because of a pressure difference, the first sealing resin **161** applied along the four sides invades the gap as shown in FIG. **16** thereby filling the gap. The amount of the first sealing resin **161** applied at this time is such that it seals the gap between the semiconductor element **103** and circuit board **101**, thereby preventing invasion of moisture and corrosion, easing a thermal stress and securing reliability at the bonded part.

According to the above-described injection method, in comparison with the method of applying the insulating sealing resin from the side end part of the semiconductor element **103** and the neighboring part **206** at atmospheric pressure, the sealing resin can be injected into the gap in a shorter time. Moreover, even if the semiconductor element **103** is as large as 15×15 mm or more, the sealing resin can be injected easily in a short time.

A heat-radiating resin **163** may be provided on the semiconductor device having the first sealing resin **161** filled in the gap as described above, in a manner as shown in FIG. **17** to cover the whole face of the semiconductor device. In **10** this case, the heat-radiating resin **163** has a thermal conductivity in a range of 0.2–2 W/mk, more preferably, 1 W/mk or larger to effectively radiate the heat generated at the semiconductor device. If alumina or a similar metallic filler of good thermal conductivity is included in the first sealing resin **161**, heat radiation efficiency of the semiconductor element **103** can be improved even without the heat-radiating resin **163**. When the metallic filler is used, the filler is coated with a resin coat so as to negate conductivity of the filler.

In place of the method of injecting the sealing resin, the semiconductor element **103** can be sealed by covering the semiconductor device **100**, for instance, with a second sealing resin **162** as shown in FIGS. **18** and **19**. The second sealing resin **162** is, e.g., film-shaped or in a liquid state. FIG. **18** shows the liquid state resin, while FIG. **19** shows a film of the resin. Concretely, after the semiconductor device **100** is heated in the chamber **173** in the pressure-reduced state, the whole face of the semiconductor element **103** is covered with the second sealing resin **162**. The working chamber **173** is returned to atmospheric pressure, and the second sealing resin **162** is set, whereby the semiconductor device **100** is sealed.

Accordingly, as compared with the method of applying and injecting the insulating sealing resin from the side end face and the neighboring part **206** of the semiconductor element **103** at atmospheric pressure, the second sealing resin can be applied in a short time in the form of a sheet, which can cope with a size increase of the semiconductor element **103**.

Similar to the case when the first sealing resin **161** is used, the heat-radiating resin **163** may be additionally provided, or alumina filler or the like may be included in the second sealing resin **162**.

The first sealing resin **161** and second sealing resin **162** are preferably of epoxy or acrylic-series, more preferably composed of a material containing an epoxy component. The first sealing resin **161** and second sealing resin **162** may be thermoplastic resin, not restricted to thermoset resin.

In the above semiconductor devices **100**, **110**, **115**, **116**, **155**, the projecting electrodes **104** are connected to the electrodes **102** on the circuit board **101** via the conductive adhesive **106**. However, the conductive adhesive **106** is not necessarily required. FIG. **23** represents a semiconductor device **211** wherein the semiconductor element **103** and circuit board **101** are fixed to each other only by the insulating adhesive **107**, without using the conductive adhesive **106**. Since the insulating adhesive **107** has shrink properties, the semiconductor element **103** and circuit board **101** are pulled toward one another when connected via the insulating adhesive **107**, and consequently the projecting electrodes **104** are butted and electrically connected to the electrodes **102** on the circuit board **101**.

Even when the semiconductor element **103** and circuit board **101** are fixed only by the insulating adhesive **107** as described above, the projecting electrodes **104** are surely connected to the electrodes **102** on the circuit board **101** via the insulating adhesive **107**. However, it is better to also use the conductive adhesive **106** to enhance connection reliability as described earlier.

Although the semiconductor element **103** is flat in the foregoing example, the mount method is not limited to the example and is applicable to a spherical semiconductor element **213** as shown in FIG. **24**. A semiconductor device **215** is obtained with the spherical semiconductor element mounted to the circuit board with the use of the mount method of the above embodiment.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

What is claimed is:

1. A method for mounting a semiconductor element to a circuit board, comprising:

disposing an insulating adhesive, having a property of shrinking upon being set, at least at either of confronting faces of the circuit board and the semiconductor element;

registering said circuit board and said semiconductor element such that an electrode on said circuit board corresponds to a projecting electrode on said semiconductor element;

coupling said confronting faces of said circuit board and said semiconductor element to one another via said insulating adhesive;

setting said insulating adhesive such that said electrode on said circuit board and said projecting electrode on said semiconductor element become electrically interconnected through shrinkage of said insulating adhesive, whereby said semiconductor element and said circuit board become fixed in a coupled state; and then

injecting a sealing resin agent into a gap between said circuit board and said semiconductor element from a side end face of said semiconductor element and portions of said semiconductor element that neighbor said side end face, wherein injecting the sealing resin agent into the gap between said circuit board and said semiconductor element includes

(i) subjecting said circuit board and said semiconductor element to a sub-atmospheric pressure,

(ii) applying said sealing resin agent to an entire periphery of said semiconductor element along said side end face and said portions of said semiconductor element that neighbor said side end face under the sub-atmospheric pressure so as to seal said gap, and

(iii) bringing said circuit board and said semiconductor element to atmospheric pressure such that said sealing resin agent applied to said side face and its neighboring portions of said semiconductor element invades said gap as a result of the difference between the sub-atmospheric pressure and the atmospheric pressure.

2. A method for mounting a semiconductor element to a circuit board, comprising:

disposing an insulating adhesive, having a property of shrinking upon being set, at least at either of confronting faces of the circuit board and the semiconductor element;

registering said circuit board and said semiconductor element such that an electrode on said circuit board corresponds to a projecting electrode on said semiconductor element;

coupling said confronting faces of said circuit board and said semiconductor element to one another via said insulating adhesive;

setting said insulating adhesive such that said electrode on said circuit board and said projecting electrode on said semiconductor element become electrically interconnected through shrinkage of said insulating adhesive, whereby said semiconductor element and said circuit board become fixed in a coupled state; and then

subjecting said circuit board and said semiconductor element to a sub-atmospheric pressure;

covering said semiconductor element with a sealing resin agent under the sub-atmospheric pressure; and

bringing said circuit board and said semiconductor element to atmospheric pressure so as to seal said semiconductor element on said circuit board with said sealing resin agent.

3. The method according to claim 2, wherein

said sealing resin agent is a resin having a property of softening by application of heat,

covering said semiconductor element with the sealing resin agent under the sub-atmospheric pressure includes heating said sealing resin agent under the sub-atmospheric pressure; and

bringing said circuit board and said semiconductor element to said atmospheric pressure so as to seal said semiconductor element on said circuit board with said sealing resin agent includes bringing said sealing resin agent to said atmospheric pressure and setting said sealing resin agent.

4. The method according to claim 2, further comprising:

coating said sealing resin agent with a heat radiating resin after said semiconductor element is sealed by said sealing resin agent.

5. The method according to claim 2, wherein said sealing resin agent is film-shaped when used to cover said semiconductor element.

6. The method according to claim 2, wherein said sealing resin agent is in a liquid state when used to cover said semiconductor element.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,651,320 B1
DATED : November 25, 2003
INVENTOR(S) : Yoshihiko Yagi et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [57], **ABSTRACT**,
Line 25, please replace "device whereby" with -- device produced by the method, whereby --.
Line 28, please replace "stabilized low." with -- stabilized to be low --.
Lines 31-33, please replace "adhesive which are interposed between an electrode on the circuit board and the projecting electrode and set in the same process." with -- adhesive. The conductive adhesive is interposed between an electrode on the circuit board and a projecting electrode, and is set in the same process as is insulating adhesive --.
Line 37, please replace "stabilized low." with -- stabilized to be low. --.

Signed and Sealed this

Eighteenth Day of January, 2005

JON W. DUDAS
Director of the United States Patent and Trademark Office